Small-Lot Production: Key to High Productivity and Quality in Japanese Auto Manufacturing

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Managers around the world, frustrated at the levels of productivity, cost, and quality achieved by Japanese automakers, have often complained that what Japanese companies do is unique. Visitors to Japan often leave convinced that without high-quality Japanese workers and their special culture, including their willingness to cooperate with management, the performance of Japan in, say, auto manufacturing cannot be duplicated. But we now know this is not necessarily the case. Japanese-run automobile plants located in Tennessee (Nissan), Ohio (Honda), and California (Toyota-GM) have demonstrated levels of productivity and quality comparable to what Japanese workers and managers have achieved in Japan.[1] A major reason is that the key to the performance of Japanese firms in auto manufacturing lies as much if not more in their approach to production management as any peculiar characteristics of Japanese workers in Japan.

Compared to the Japanese, U.S. and European companies may have been at a disadvantage due to the absence of clear

industrial policies, inadequate quality-control programs, too much confrontation between management and labor, poorly educated blue-collar employees, and less ethnic homogeneity in the work force. But, historically, U.S. and European automakers who founded the industry performed well -- until auto producers in Japan set new standards of productivity, general manufacturing efficiency, and product quality at low cost. The Japanese accomplished this primarily by modifying, beginning in the 1930s, American and European equipment, techniques, and traditional assumptions about production management.[2]

For non-Japanese managers in autos and other industries such as electronics, the challenge of the past decade has been to stop falling behind. But learning to match the standards Japan has set requires an analysis of precisely how leading Japanese companies got to where they are. In particular, it seems important to determine how they transformed the dirty, disorganized, remarkably inefficient plants U.S. Occupation observers saw in the late 1940s and early 1950s, into perhaps the most superbly conceived and run manufacturing organizations in the world.[3]

THE USUAL EXPLANATIONS

There are several common explanations as to how Japan's automakers evolved and came to dominate the world industry. Since car mass production began in the U.S., it is often assumed that Japanese firms copied or imported American manufacturing equipment and techniques reflecting the best American thinking and years of experience. And then the Japanese, or so the story usually goes, did more: They paid greater attention to factory details and achieved better implementation -- aided by factors like ethnic homogeneity, better educated employees, and "harmony" between managers and workers, combined with now-famous techniques that supposedly grew out of Japanese culture and geographical conditions: near-fanatical attention to cleanliness and quality, group cooperation as seen in quality circles, "just-in-time" production using "kanban" cards to control manually and precisely the process flow and parts deliveries.

Nor is this scenario the only explanation for Japan's high productivity and low costs. Another is the large investments in plant and equipment, which appear to give Japanese workers an edge in capital. Yet another is huge economies of scale achieved in the domestic market during the 1970s, which may have made it possible for Japanese automakers to match international standards of productivity and costs and then begin large-scale exports to the U.S. and Europe.

WHAT HISTORICAL ANALYSIS REVEALS

Studying the historical evolution of the two leading Japanese automakers, Nissan and Toyota, as well as some relevant numbers, suggests that the explanations outlined above need some clarifications and corrections.

One: Japanese automakers did not all copy and import American or European equipment and production-management techniques. There was great temptation to do so, and most (Nissan, Isuzu, Mitsubishi, Hino) did, during the 1930s and 1950s. In fact, the assembly and manufacturing of European models under license accounted for about 30% of Japanese car production during 1953-1959.[4] But Toyota deliberately avoided copying foreign models or techniques exactly. Instead, it developed in-house skills and began an innovation process that led eventually to the highest levels of productivity in the world.[5]

Two: The Japanese success in automobiles is not, therefore, simply a matter of "better implementation." Led by Toyota, in varying degrees, Japan's automakers all made critical changes in U.S. procedures and concepts. It was these innovations or modifications of foreign practices and assumptions that led directly to higher worker output, better quality, and savings in

areas such as inventory turnover.

Three: High productivity -- surpassing U.S. averages -- was not due simply to huge economies of scale derived from the domestic market during the 1970s. Toyota and then Nissan matched or surpassed U.S. output levels per worker during the late 1950s and early 1960s, and at merely 3% to 5% of General Motors' sales volume in 1965! (Exhibits 1 and 2)

Four: Nor can the Japanese performance in auto manufacturing be attributed simply to higher levels of capital investment. Nissan and Toyota matched and then doubled U.S. productivity levels in the 1960s with less capital per employee. (Exhibit 3)

Some statistics are difficult to interpret. In 1983, for example, workers at Nissan and Toyota had 2 to 2.5 times as many fixed assets as their counterparts at GM, Ford, and Chrysler--creating the impression that Japanese workers were twice as productive because of investment levels that were twice as high (see Exhibit 3). Not so. The amount of fixed assets (plant, property, and equipment) required to produce one vehicle by the late 1970s and early 1980s was roughly equivalent in Japan and in the U.S. (Exhibit 4) Only because "throughput" per worker per year was twice as high in Japan did workers at Nissan and Toyota show twice as many fixed assets each. But it was actually labor and the overall Japanese production systems, not capital, that

were twice as productive as their U.S. counterparts.[6]

KEY FACTOR: THE NEED TO PRODUCE IN SMALL LOTS

In attempting to explain Japan's economic performance since the mid-1950s, scholars, government officials, and businessmen alike have debated the contribution of industrial policy, cultural harmony, education, "luck," or other factors that seem unique to Japanese society and history. But a simple "fact" emerges from studying the history of the Japanese auto industry and talking to Japanese production engineers: The overriding concern that drove Japanese automakers to become more efficient than U.S. companies was the need after World War II to master small-lot production. That is, companies had to produce a growing variety of cars and trucks at extremely low volumes and at the lowest possible costs, to accommodate a very small but increasingly sophisticated domestic market with a growing number of competing firms.[7]

Attempts by Japan's Ministry of International Trade and Industry (MITI) to "rationalize" the auto industry largely failed. First, after World War II, MITI tried to convince firms to abandon passenger car production. Then, during the 1960s, MITI wanted to reduce the number of producers competing in the industry, to raise scale economies for any one manufacturer.

Company executives at nearly a dozen firms saw great potential in the auto industry and repeatedly refused to bow to the wishes of government bureaucrats.[8]

At Toyota in particular, this "need" to produce in small lots inspired modifications in equipment or techniques based on fundamental engineering practices and concepts found in U.S. textbooks and non-automotive factories such as in the military aircraft industry. And these improvements, more than anything else, enabled Japanese managers to overturn traditional American assumptions about minimum efficient scales, the value of large manufacturing lots and buffer inventories, the importance of worker and machine specialization, the role of labor and suppliers in the manufacturing process, as well as the limits to worker productivity and, ultimately, to the levels of quality achievable at a given cost.

Japanese auto production in 1950 consisted of 31,597 cars and trucks -- little more than one days' output for the U.S. auto industry. (Exhibit 5) Four local companies shared the market--Nissan, Toyota, Isuzu, and Hino --and half-a-dozen more would enter the field by the early 1960s -- Mitsubishi, Honda, Mazda, Daihatsu, Suzuki, and Prince (which merged with Nissan in 1966). Japanese automakers could use American mass-production equipment and techniques for trucks made during World War II, since they produced these models in relatively large runs (compared to

passenger cars), and with few changes. It was possible to machine or stamp thousands of identical components, as U.S. manufacturers did for much higher volumes, and store the excess for future months. It was expensive to pay for equipment in this way, but possible with high prices under the protected market that existed in Japan from 1936 to 1945 and then from 1953 until the mid-1970s.[9]

Nissan's history illustrates this strategy. In the mid-1930s, Nissan entered into an agreement with Graham-Paige (which sold out to Dodge before World War II) and bought specialized and expensive American machine tools and stamping presses to produce the U.S. company's standard-size truck. A dozen high-salaried American engineers came to Japan for two years and set up operations. Nissan then sold nearly all its output, at rather high profit margins, to the Japanese army until 1945, and continued to make the same truck and engine, with only minor changes, until the late 1950s.[10]

After World War II, however, the military market disappeared. To survive, Nissan and other Japanese automakers had to make the transition from trucks and buses (about 95% of production in 1950) to passenger cars. Car production at the leader Japanese automakers rose from merely 5% of output in 1950 to about 65% in 1970. (Exhibit 6) Passenger vehicles also came to require far more equipment and options, as well as a variety of

styles and more frequent model changes, especially as the Japanese companies improved their vehicles incrementally.

For cars as well as for trucks, annual model volumes were extremely small during the 1950s and for much of the 1960s. For example, Nissan in 1950 produced only two major products -- one standard-size truck and one small truck. The few cars it made were actually the small truck fitted with a car body.[11] The number of new models increased even while Nissan was a very small-scale producer by world standards. The average annual volume for Nissan car models increased from a minuscule 900 in 1950 to a still small 18,000 in 1960 and 42,000 in 1965. In comparison, Ford, as early as 1923, had achieved an annual volume for the Model T of over 2 million units.[12] Average annual volumes for Nissan cars were still relatively low during the 1970s and fell under 100,000 after 1980 as Nissan introduced additional new models. Similar circumstances prevailed at Toyota, which had an average car-model volume of 100,000 in 1983.[13] (Exhibit 7)

Changing market requirements, not cultural predispositions, forced Nissan, Toyota, and other Japanese automakers to confront a seemingly intractable dilemma: the traditional auto factory's preference for mass producing huge lots of standardized components; and the Japanese market's demand for a rising variety of products in small amounts and at falling prices. The Japanese

government helped by limiting imports to about 1% of the Japanese market following the postwar U.S. Occupation, although prices for Japanese-made vehicles dropped between the early 1950s and the early 1970s as the number of local firms competing for the few domestic customers tripled by the early 1960s.[14]

Prices (and, presumably, unit costs) in Japan still did not match international levels for comparable small cars until the late 1960s.[15] Yet an additional incentive to increase productivity and reduce costs was the desire of Japanese automakers, beginning with their first attempts in the late 1950s, to expand car sales beyond the limits of the small domestic market.[16] Exports increased slowly in importance, from less than 4% of total production to just over 20% as late as 1970. As quality rose and small cars became more popular in the U.S., Japanese exports passed 50% of output in 1977.

A PROBLEM WITH A SOLUTION

But in the lean years following World War II, Japanese managers were not quite sure how to accommodate changing market needs and potential export requirements of low-cost, high-quality vehicles. U.S. engineers and companies had designed much of their equipment and influenced many of their experiences. Not surprisingly, many Japanese managers, especially at Nissan, first

believed that the best way to compete in automobile manufacturing was to copy as closely as possible the systems perfected at Ford, GM, and other mass producers.[17]

The U.S. "paradigm" involved a set of techniques and concepts that assumed the following were most efficient: high levels of worker and equipment specialization; extensive automation; long production runs on huge machines requiring long set-up times; large manufacturing scales with buffer stocks to keep the expensive machines and specialized workers constantly active, making as many parts or assemblies as possible in a set period of time; and the "push" concept of production control. This involved manufacturing and delivering components according to a master schedule, which was also designed to keep most of the machines running and components coming in despite problems that might develop at a few stations or suppliers. To inspect all the components made in huge lots required too many inspectors, so companies adopted statistical sampling techniques to test a few parts and determine if an entire lot met an "acceptable quality level," even though this meant some defectives would pass through the system at every stage. U.S. automakers also tried to bring in house as much of the components production and assembly as possible, to insure acceptable levels of price, quality, and supply.[18]

In contrast, it gradually became clear to Japanese production managers that some modifications were necessary in U.S. equipment and manufacturing practices to meet the needs of their small but competitive domestic market. Not only did Japanese automakers after World War II have to manufacture in lots far smaller than were common in the U.S. or even Europe. Led by Toyota's Taiichi Ohno (bn. 1912), Japanese managers realized that the best way to do this required an increase in the "flexibility" and utilization of traditional components in their manufacturing systems -- equipment, workers, and suppliers. They also sought to lower, as much as possible, "fixed" costs for in-house personnel, factory or warehousing space, and equipment, as well as variable costs, such as for in-process or finished-goods inventories.

Individual Japanese automakers implemented this strategy with varying degrees of success and in different years, yet all pursued three basic policies: One, beginning in the late 1940s at Toyota and in the mid-1950s at Nissan, was the "just-in-time" concept for in-house production or assembly and deliveries of components. This itself required several departures from U.S. practices: faster setup times for machine tools and stamping presses (techniques first written about in the U.S. and incorporated in American equipment such as Danley stamping presses), so each piece of equipment could be used for different models or components without long waiting times; tighter

synchronization between subassembly production, parts deliveries, and final assembly, to increase equipment utilization and reduce in-process inventories; mixed scheduling of different components or models on single machines or assembly lines, to avoid specialized but under-utilized equipment and workers; and broader job specifications, so managers could maintain the just-in-time pace by shifting workers to different jobs as needed at any given moment.[19]

These modifications resulted in higher productivity as workers ended up operating several different machines simultaneously, and doing some of their own maintenance and inspection, especially in times of slow demand. The discipline imposed by the just-in-time pace along with small-lot production also tended to improve quality, as workers paid more attention to what they were doing and could no longer rely on large buffer stocks if they made mistakes in processing or assembly. Fewer defectives, furthermore, resulted in higher yields -- another boost to productivity.[20]

A second policy was to gain some benefits from the concept of scale economies, even at low volumes compared to the U.S., by reducing complexity in product designs and manufacturing. Beginning in the late 1940s, Nissan and Toyota did this by standardizing components across different car and truck lines (until the later 1950s), reducing the frequency of model changes,

and limiting the number of options available to customers.[21]

The third policy involved decreasing levels of in-house vertical integration between components production and final assembly, while building up networks of lower-wage subsidiaries and loosely affiliated subcontractors.[22] Toyota started the process of establishing a network of suppliers in the late 1930s and founded all its major subsidiaries during the 1940s. Nissan took longer to set up a supplier network, although, by the end of the 1970s for Nissan, and as early as the 1940s for Toyota, the largest Japanese automakers demonstrated levels of "group integration" (the percentage of total costs accounted for in-house or at affiliates in which Nissan or Toyota held a minimum 20% equity share) that were far higher than the most integrated U.S. automaker, General Motors. (Exhibit 8) This made it possible to achieve many of the benefits of vertical integration without the higher personnel or other costs that formal integration would have required.

For example, in 1983, for each small car they produced, about 50% of the costs at Nissan and Toyota were accounted for by subsidiaries and other affiliated subcontractors (see Exhibit 8). These companies, furthermore, paid wages equal to merely 77% of those received by Toyota workers and 81% received by Nissan workers. (Exhibit 9) Wages were lower at suppliers, but productivity gains were not. By working with these companies to

improve their production systems as well as the quality of their components or assembly services, value-added productivity at Nissan and Toyota subsidiaries tripled between 1960 and 1983. (Exhibit 10) This was a rate of increase faster than the 2.4- and 2.8-fold improvements registered at Nissan and Toyota, respectively, in this same period.[23]

THE TOYOTA "REVOLUTION"

Toyota, unlike Nissan, started out in the 1930s without buying American design and manufacturing technology. The founder of the company, Kiichiro Toyoda (1894-1952), designed his first vehicle by copying a Ford chassis, a Chevrolet engine, and a Chrysler DeSoto body -- combining the "best" features of each U.S. manufacturer. The first truck broke down on the way to the showroom, portending a series of technical problems in Toyota vehicles that took more than a decade to overcome.[24] Nissan, by importing what was essentially a Dodge truck, went quickly into "mass production" in the mid-1930s and turned out a vehicle comparable to U.S. models -- while establishing a predilection for American manufacturing equipment and practices that managers carried through to at least the 1970s.[25]

In contrast, Kiichiro and other Toyota managers realized they would need to improve vehicles frequently, since they were

experimenting with designing cars and trucks independently. In particular, Kiichiro's objectives were to cultivate in-house design skills (he could not afford to buy the blueprints, equipment, and American assistance Nissan purchased), as well as to set up an inexpensive production system for low volumes. Since the early vehicles were unreliable, the Japanese military would not buy all Toyota's output. Nissan, on the other hand, had more orders than it could fill.

To solve its unique problems, Toyota, again departing from Nissan, bought universal machine tools and small stamping presses that were affordable and easily adaptable to model changes. This was the beginning of the "flexibility" in the Toyota production system that, after World War II, helped the company introduce numerous new models, for the domestic and export markets, quickly and cheaply. Again, unlike Nissan, Isuzu, Hino, and Mitsubishi, during the 1950s Toyota chose not to become affiliated with a European or U.S. auto producer to learn modern design and automation technology developed in the 1940s and early 1950s.

Benefiting from the versatile equipment first purchased in the 1930s and from the direction of Ohno, who rose to executive vice-president in the company, Toyota gradually introduced a series of innovations in manufacturing that rival the achievement of Henry Ford with the Model T. Ohno joined Toyota in 1943 from a loom-machinery producer, with no experience in automobiles, no

predilections in favor of U.S. methods. This one manager initiated the planning for a virtual "revolution" that would result in extraordinarily high levels of productivity and inventory turnover, and help Toyota become one of the most efficient and profitable companies in history.

The development of the key techniques used in Toyota's production system occurred between 1948 and 1965:[26] (See also Exhibit 11)

1948: Ohno instituted a "pull" system in the machining shop for engines, with each worker moving back to the previous station to retrieve work in process, just at the necessary time in only the amount needed for immediate processing. He first read about the idea of a pull system in a Japanese newspaper which described this practice in the U.S. aircraft industry during World War II and in U.S. supermarkets. This contrasted with the traditional "push" systems used at Nissan and other automakers in the U.S., Japan, and Europe, where the flow of components and information signalling production moved in a forward direction, according to a schedule, whether or not stations were ready to receive the components. The push system was not well suited to small-lot production and tended to build up in-process

inventories whenever stations fell behind, due to machinery breakdowns or other factors, or when sales fell and production schedules were not revised downward. Toyota management wanted to control in-process and finished-goods inventories because of large financial losses associated with the collapse of the military market and postwar inflation.

1949: The pull system in the machining shop allowed Toyota to end the intermediate stockpiling of engines.

Ohno also made workers in the machining shop operate several machines each, rather than specialize (as did autoworkers at Nissan as well as U.S. and European companies), because demand was low and there was not enough work to keep all machines operating constantly. This procedural change improved worker productivity.

Ohno then asked production workers to conduct their own inspections. This improved quality <u>on the line</u> and raised worker output by cutting down on non-productive inspection staff.

1950: Toyota extended the pull concept to marketing through the policy, prompted by financial difficulties and demanded by company bankers, of limiting production to

orders received by Toyota Motor Sales from dealers.

Toyota synchronized engine and transmission machining with final assembly, to reduce further in-process inventories.

Indicator lights introduced on the engine lines alerted supervisors to problems.

1953: Ohno introduced an early "kanban" system, using the exchange of paper tags to signal processing operations or parts production, into the machining shop. The Japanese called this the "supermarket method," since it mimicked the practice in U.S. supermarkets where customers went to stores to buy what they wanted when they wanted it, rather than store goods, while the supermarket replaced items on shelves as it sold them.

To simplify manufacturing, procurement, and conveyance Toyota also instituted a standardization program for car and truck components.

1955: Toyota synchronized its body and final assembly shops to eliminate more in-process inventories.

Controls introduced on parts deliveries further cut

inventories.

Toyota started to mix the loading of components in small lots for machine tools and to mix model runs on final assembly lines to raise equipment utilization as well as lower inventories.

Line-stop buttons introduced on assembly lines gave workers authority to halt production if they noticed defects or if other problems arose.

1957: Indicator lights installed on all production lines alerted supervisors outside the machining shop to problems.

1959: A control system for in-house to in-house and in-house to outside conveyance again cut in-process inventories and waiting time.

1961: Toyota introduced the kanban system to some outside parts suppliers.

1962: Toyota then extended the kanban system to all in-house shops, placing the entire company on a small-lot, pull system.

Foolproof devices added to machine tools helped prevent defects and over-production.

As an example of rapid setup, Toyota lowered stamping-press changeover times for dies from 2 or 3 hours in previous years to 15 minutes, through techniques such as automating as much of the process as possible, doing preparations for the changeover while machines were running, and training teams to specialize in setup. Rapid setups increased equipment utilization and made small-lot production more economical, as well as helped reduce in-process inventories by cutting lead times.

1963: Ohno now asked workers to operate an average of 5 machines each, compared to 3 to 4 since 1949, 2 in 1947, and 1 in previous years. This raised labor productivity.

1965: Toyota extended the kanban system to all outside parts deliveries, reducing in-process inventories to a minimum.

IMPACT ON PRODUCTIVITY AND INVENTORY TURNOVER

The results of Toyota's techniques were impressive.

Vehicles per worker per year (unadjusted for vertical integration or capacity utilization) tripled at Toyota between 1955 and 1957 and then rose another 60% by 1964. (Exhibit 12 By this time, Toyota had passed productivity levels at GM, Ford, and Chrysler (see Exhibit 1). Nissan did not adopt the kanban or pull system, and focused on improving its levels of automation, as U.S. and European companies did. But, at roughly the same time or a year or two behind Toyota, Nissan also worked at reducing setup times, improving in-house synchronization, and controlling parts deliveries. Gross productivity levels at Nissan then increased five-fold between 1955 and 1964, an improvement comparable to Toyota, although Nissan was still behind Toyota in productivity and has never caught up, despite doubling U.S. productivity levels.

Perhaps the most remarkable effects of Toyota's pull system, and the clearest contrasts with Nissan and U.S. firms, can be seen in inventory turnover (average total inventories divided into sales). This is an effective measure of how well a company controls in-process stocks as well as stockpiles of finished goods. In the mid-1950s, Toyota, Nissan, GM, Ford, and Chrysler all had relatively low turnover levels. In fact, the U.S. companies made no progress in this area between the 1950s and the early 1980s --until they began experimenting with a limited "just-in-time" concept around 1982. (Exhibit 13).

Nissan's factories and suppliers are more dispersed than Toyota's. From the 1930s, Nissan has also been more committed to automation and specialized equipment than Toyota, and in the 1960s introduced a computerized push-system for production control resembling "Materials Requirement Planning" (MRP) systems common in the U.S. Nissan thus manufactures automobiles according to a computer-generated schedule that is not tied as directly to market demand and is not adjusted almost "instantaneously" to changes in shop conditions or at suppliers, as in Toyota's kanban system. The result is that Nissan must keep larger buffer inventories to guard against disruptions in the supply system or inaccurate computer information.[27]

To accommodate product diversity at small volumes and to reduce warehousing requirements in the expensive urban area of Tokyo and Yokohama, in the 1950s and early 1960s, Nissan began modifying machine tools to get more rapid setup times and requiring more frequent parts deliveries than in the U.S. These practices brought Nissan to a level of inventory turnover beyond U.S. firms. Yet it is still considerably behind Toyota, and only since 1979, when Nissan adopted kanban for outside suppliers located more than 20 minutes or so from its factories (nearer suppliers are connected by on-line terminals), did the company make substantial progress in inventory turnover beyond what it achieved by the mid-1960s. (Exhibit 14)

One indication that Toyota was not always so different from American automakers can be seen in the fact that its inventory turnover in 1955 was no higher than the average for U.S. firms from the mid-1950s through the early 1980s. Only with better synchronization among processes and with parts deliveries, mixing runs in parts production and assembly, and experiments with kanban and the pull system, did turnover double between 1955 and 1956. It fell for a few years while Toyota built another plant but then rose significantly again between 1962 and 1963 (when Toyota adopted the kanban system for all in-house shops) and in 1965-1966 (when Toyota brought suppliers onto the kanban system). Nor was rapid turnover due to rapid increases in sales. Even when production volume fell 8% in 1974 following the first oil shock, Toyota maintained a turnover level of more than 20 times--twice as high as U.S. firms and Nissan.

After perfecting these techniques by the mid-1960s, Toyota engineers and consultants taught their production system to major subsidiaries and affiliates such as Hino and Daihatsu. These efforts helped produce significant rises in turnover (as well as productivity) at nearly all subsidiaries in the Toyota group. Companies affiliated with Nissan followed, as did Mazda in the mid-1970s.[28] But foreign competitors should find some consolation in realizing that not all Japanese automakers have been able to implement just-in-time systems as effective as Toyota's. This can be seen not only at Nissan, but also at

Honda, Fuji Heavy Industries (Subaru), and Isuzu, which have turnover rates comparable to GM, Ford, and Chrysler. (Exhibit 15)

IMPLICATIONS FOR MANAGERS

The "quality" (education and discipline) of workers found in Japan has no doubt been important, too. But Japanese managers after World War II also reflected on the labor difficulties U.S. companies had in the 1930s and then planned how to insure more cooperation from workers and to reduce personnel costs. They did this by undercutting industrial unions and setting up company unions dominated by white-collar workers; frequently promoting union officials to management positions, raising the likelihood that union leaders would cooperate; firing large numbers of workers after World War II and then offering "lifetime" employment to select groups of employees in return for their cooperation; and using low-wage subcontractors highly dependent on the original equipment manufacturers to produce 70% or more of the components (by value) of each Japanese car.[29]

Management-labor relations and industrial unions have evolved differently in the U.S., and it is unlikely that American managers will be able to control workers to the same extent as Japanese companies. But labor differences must not become an excuse for less efficient manufacturing practices. Equally

important to understanding what happened in the Japanese auto industry is what went on in the U.S: By the early 1960s, American managers came to view automobile manufacturing as a stable or "mature" technology, with certain limits to productivity, minimum efficient scales of production, unit costs, quality, and the ability of workers and suppliers to cooperate (or be coerced), as well as to contribute to improving the overall production system. The original "American paradigm" characterized by large production runs, push-type of scheduling, high levels of automation and worker specialization, with large numbers of inspectors using statistical sampling, dominated the thinking, and the goals, of U.S. as well as European managers.

There was nothing particularly "wrong" with this approach to manufacturing. It proved to be remarkably effective for high-volume production of a limited number of models. But then market conditions and financial constraints in Japan after World War II led Toyota and then other Japanese automakers to challenge American assumptions and master small-lot production. This produced greater efficiency in a variety of areas: higher worker output and utilization rates for machinery, faster inventory turnover, and even higher quality, since "just-in-time" systems did not tolerate defectives or equipment breakdowns, and Japanese workers producing in smaller lots found they paid greater attention to what they were doing -- as opposed to American workers making thousands of components of one type, with large

piles of buffer stocks to draw on if they made mistakes.

In sum, the history of Japan's auto industry is a story both of American lapses and Japanese innovations. These innovations involved a spectrum of changes in American production technology, with Toyota as the most radical and with most other Japanese automakers, typified by Nissan, incorporating less extensive modifications of U.S. practices and equipment. (Exhibit 16)

Critical to the Japanese success in auto manufacturing was that managers such as Toyota's Ohno did not accept U.S. practices as the only viable way to produce automobiles, and did not believe that U.S. firms had reached the limits possible for capital and worker productivity, quality, inventory turnover, or the effective integration of equipment, labor, and suppliers. And there was nothing mysterious or miraculous about what Japanese automakers accomplished. They responded to specific market conditions, creatively using techniques, developed first in the U.S., for new applications in automobile production, and ultimately establishing higher standards of efficiency. If competing managers learn nothing else from this story, they should at least come away convinced that improvement, sometimes dramatic improvement, may never be impossible -- even in industries that seem old, stable, and quintessentially Western.

REFERENCES

1. Evidence for this statement comes from numerous reports during 1985-1986 in The New York Times, The Wall Street Journal, and Consumer Reports regarding the quality and cost of Honda Accords, Nissan Sentras, and Chevrolet Novas (nearly identical to the Toyota Corolla and made by the GM-Toyota joint venture) produced in the U.S.

2. For a fuller treatment of the arguments in this article see Michael A. Cusumano, The Japanese Automobile Industry: Technology and Management at Nissan and Toyota (Harvard University Press, 1985).

3. Vivid descriptions of the chaos and low productivity that existed in the postwar Japanese auto industry can be found in the company histories of Nissan and Toyota, the two largest auto producers in Japan, then and now: Nissan Jidosha Kabushiki Kaisha, Nissan Jidosha sanju-nen shi (A thirty-year history of Nissan Motor), Tokyo, 1964, and Toyota Jidosha Kabushiki Kaisha, Toyota Jidosha sanju-nen shi (A thirty-year history of Toyota Motor), Toyota City, 1967. Also of historical importance in documenting that the Japanese did not always establish clean and well-organized factories are several field reports written by American engineers from Western Electric, working as part of the U.S. Occupation forces, who visted Fujitsu, Matsushita, Oki Electric, Sony, and other Japanese communications equipment producers in 1949: Charles Protzman and Homer Sarasohn, "Survey of Six Japanese Manufacturing Companies," Civil Communications Section, Industry Division, 24 February 1949--13 June 1949, Modern Military Records Group, Box 3190B, Washington National Records Center, Suitland, Md. For a discussion of these engineers and their observations as well as contributions to improving Japanese management see Kenneth Hopper, "Creating Japan's New Industrial Management: The American's as Teachers," Human Resource Management, Summer 1982; and Ghary Gappelberg, "'CCS' and Modern Japanese Management: The Influence of American Management Concepts on the Japanese Communications Industry, 1946-1950," Harvard College B.A. Thesis, Department of History, March 1986.

4. Based on data in Amagai Shogo, Nihon jidosha kogyo no shiteki tenkai (The historical development of the Japanese automobile industry), Tokyo, Aki Shobo, 1982, p. 136, and the Japan Automobile Manufacturers Association, Nihon no jidosha kogyo (The Japanese automobile industry), annual. Please note that Japanese names in the text of this paper are in the English order, with surnames following given names. In the notes, however, Japanese authors are listed in the traditional Japanese order, with

surnames first.

5. Examples of evidence that the Toyota decision not to link up with foreign producers was indeed deliberate can be found in the following: Toyoda Kiichiro, "Toyota Jidosha ga konnichi ni itaru made" (Toyota Motor up to the present, September 1936), reprinted in Ozaki Masahisa, Toyoda Kiichiro shi, Tokyo, Jikensha, 1955, pp. 172-173; Shotaro Kamiya, My Life with Toyota, Nagoya, Toyota Motor Sales, pp. 61-70; Toyota Jidosha sanju-nen shi, pp. 346-348.

6. My thanks to Kim Clark of the Harvard Business School for helping me interpret these numbers from an economist's standpoint.

7. A good discussion of this need to produce in small lots and the response at Toyota can be found in Ohno Taiichi, Toyota seisan hoshiki (The Toyota production system), Tokyo, Daiyamondo, 1978. On 18 March 1983, I also interviewed Mr. Ohno, the founder of Toyota's kanban system. He retired from Toyota as a senior vice-president in 1978.

8. On Japanese government policy toward the auto industry, see Hiroya Ueno and Hiromichi Muto, "The Automobile Industry of Japan," in Kazuo Sato, ed., Industry and Business in Japan, New York, Croom-Helm, 1980, pp. 148-155; Masaru Udagawa, "Historical Development of the Japanese Automobile Industry, 1917-1971: Business and Government," Keiei shirin 19.4:31-46 (January 1983); Ira C. Magaziner, "Japanese Industrial Policy: Source of Strength for the Automobile Industry," in Robert E. Cole, ed., The Japanese Automobile Industry: Model and Challenge for the Future? Ann Arbor, Michigan Papers in Japanese Studies, No. 3, 1981, pp. 79-83.

9. Regulations on imports can be found in Jidosha Kogyo Shinko Kai (Automobile Promotion Association), Jidosha hakubutsukan chosa hokokusho (Automobile museum survey report), Tokyo, Vol. I, May 1978; and Nissan Jidosha Kabushiki Kaisha Chosa-bu (Nissan Motor Business Research Department), Jidosha kogyo handobukku (Automobile industry handbook), Tokyo, 1983, p. 373.

10. Sources for these comments on Nissan include the company history as well as Jidosha Kogyo Shinko Kai (Automobile Promotion Association), ed., Nihon jidosha shi kojutsu kiroku shu (Recordings of oral interviews on the history of the Japanese automobile industry), Tokyo, Vol. II, 1975; Nihon Jidosha Kogyo Kai (Japan Automobile Manufacturers Association), ed., Nihon jidosha kogyo shiko (A history of the Japanese automobile industry), Vol. II, 1967, and Vol. III, 1969; and interviews with former Nissan managers Kawazoe Soichi (2 June 1982), Sasaki Sadamichi (18 May 1982), Katayama Yutaka (31 May 1982), and Okumura Shoji (10 June 1982).

11. See Nissan Jidosha sanju-nen shi, data section.

12. Ford Annual Report, 1923.

13. For a listing of all current models see Toyota's Japanese-version of the 10-K annual report (yuka shoken hokokusho).

14. The historical movement of prices for particular models can be followed in Jidosha hakubutsukan chosa hokokusho.

15. For international price comparisons, see the book by former Nissan President Iwakoshi Tadahiro, Jidosha kogyo ron (A discussion of the automobile industry), Tokyo, University of Tokyo Press, 1968.

16. See Kamiya, pp. 74-82; Toyota Jidosha sanju-nen shi, especially pp. 456-457; and John B. Rae, Nissan-Datsun: A History of Nissan Motor Corporation in U.S.A., 1960-1980, New York: McGraw Hill, 1982, especially pp. 15-18.

17. This comment is based on interviews with former Nissan managers Okumura, Sasaki, Kawazoe, Katayama, Maeda Riichi (21 May 1982), and Matsuzaki Shiro (14 July 1982).

18. See Kirk Monteverde and David J. Teece, "Supplier Switching Costs and Vertical Integration in the Automobile Industry," Bell Journal of Economics 13.1:206-213 (Spring 1982).

19. Details on Toyota can be found in numerous sources, including Ohno, especially pp. 11-23, 36-53, 62-72, 138-141, 175-193, 217-229; Y. Sugimori et al. (from Toyota's Production Control Dept.), "Toyota Production System and Kanban System of Materialization of Just-in-Time and Respect-for-Human System," International Journal of Production Research, 15.6:553-564 (1977); Toyota Jidosha sanju-nen shi, pp. 265-271, 334-336, 421-430; Toyota Jidosha Kabushiki Kaisha, Toyota no ayumi (The path of Toyota Motor), Toyota City, 1978, pp. 342, 345-346; Shingo Shigeo, Toyota seisan hoshiki no IE-teki kosatsu (An industrial-engineering analysis of the Toyota production system), Tokyo, Nikkan Kogyo Shimbunsha, 1980; Robert W. Hall, Zero Inventories, Homewood, Illinois, Dow-Jones Irwin, 1983; and several publications by Yasuhiro Monden: "What Makes the Toyota Productiion System Really Tick?" Industrial Engineering, January 1981; "Adaptable Kanban System Helps Toyota Maintain Just-in-Time Production," Industrial Engineering, May 1981; "How Toyota Shortened Supply Lot Production Time, Waiting Time, and Conveyance Time," Industrial Engineering, September 1981; and Toyota Production System, Atlanta, Institute of Industrial Engineers, 1983. For developments at Nissan I relied on interviews with two managers responsible for production control, Kanao Kaiichi (11 April 1983) and Matsuzaki (14 July 1982 and 19 January 1983); Nissan Jidosha sanju-nen shi, pp. 73, 244-246, 330-339; Nissan Jidosha

Kabushiki Kaisha, Nissan Jidosha shashi (Nissan Motor company history), Tokyo, 1975, pp. 44-47, 375-376.

20. On the impact of just-in-time on quality see Richard J. Schonberger, Japanese Manufacturing Techniques, New York, The Free Press, 1982, pp. 15-82.

21. Product development at Nissan and Toyota can be followed through the company histories, including data series on car and truck specifications. For Nissan, see also Ikari Yoshiro, Dai-Ichi Sharyo Sekkei-bu: Bluebird no otoko-tachi (The No. 1 Chassis Design Section: Men of the Bluebird), Tokyo, Bungei Shunshu, 1981. On limitations on options and complexity in assembly, see Harbour and Associates, Inc., "Comparison of Japanese Car Assembly Plant Located in Japan and U.S. Car Assembly Plant Located in the U.S.," Berkley, Michigan, ca. 1980, pp. 12-13; and James Cook, "Where's the Niche?" Forbes, 24 September 1984, pp. 54-55.

22. On the development of subsidiaries and supplier networks, see Toyota Jidosha sanju-nen shi, pp. 180-181, 196-202, 207-210, 226-229, 272-273; Nissan Jidosha san-ju nen shi, pp. 205-206, 239, 320-321, 339-342; Nissan Jidosha shashi, pp. 31-33, 55-56, 60-61, 76-79, 178-179, 222, 229, 262, 281-284. On the vertical de-integration strategy, I relied on an article by former Nissan manager Okumura Shoji, "Jidosha kogyo no hatten dankai to kozo" (The developmental stages and structure of the automobile industry), in Arisawa Hiromi, ed., Gendai Nihon sangyo koza (Series on contemporary Japanese industry), Tokyo, Iwanami Shoten, Vol. V, 1960, pp. 327-330; and interviews with Matsuzaki and a former Nissan manager responsible for procurement and recent chairman of Nihon Radiator, Ota Hisakichi (20 May 1982).

23. See Cusumano, Table 50, p. 202-203. I deflated the value-added data using the Japanese consumer price index for automobiles and related expensives. Unadjusted value-added data on Nissan and Toyota, as well as their main subsidiaries, can be found in Nihon Seisansei Honbu (Japan Productivity Center), Fuka kachi bunseki (Value-added analysis), Tokyo, annual since 1960.

24. The discussion of Toyota is based primarily on Toyota Jidosha sanju-nen shi; Ozaki and Toyoda Kiichiro in Ozaki; Okumura; Kamiya; Morikawa Hidemasa, "Toyoda Kiichiro," in Morikawa Hidemasa et al., Nihon no kigyoka (Japanese entrepreneurs), Tokyo, Yuhikaku Shinsho, Vol. III, 1978; Kamiya interview in Morikawa Hidemasa, ed., Sengo sangyo shi e no shogen (Accounts of the history of postwar industry), Tokyo, Asahi Shimbunsha, Vol. II, 1977; Ohno; and interviews with Ohno and Okumura.

25. The following discussion of Nissan is based primarily on Nihon jidosha kogyo shi kojutsu kiroku shu; Aikawa Yoshisuke, Watakushi no rirekisho (My career), Tokyo, Nihon Keizai

Shimbunsha, Vol. XXIV, 1965; Ozawa Chikamitsu, Aikawa Yoshisuke den (Biography of Aikawa Yoshisuke), Yamaguchi, Yamaguchi Shimbunsha, 1974; Nihon jidosha kogyo shiko, Vol. II; Nissan Jidosha sanju-nen shi; Ikari; and interviews with Aikawa Yaichi (7 September 1982), Katayama (31 May 1982), Sasaki, Maeda (21 May 1982), Asahara Hideo (19 May 1982), Okumura, Matsuzaki, and Kawamata Katsuji (8 June 1982).

26. This chronology is based primarily on Ohno, especially pp. 228-229; my interview with Ohno; and Toyota Jidosha sanju-nen shi.

27. These comments are based on interviews with Matsuzaki and Kanao, as well as Nissan Jidosha sanju-nen shi, especially pp. 72-73, 244-246, 330-339, 375-388; and Nissan Jidosha shashi, pp. 44-47, 375-376.

28. For a discussion of Mazda (formerly named Toyo Kogyo), see Harvard Business School (Kim Clark), "Toyo Kogyo Co. LTD (A)," Boston, HBS Case Services No. 9-682-092, 1982; and Richard Pascale and Thomas Rohlen, "The Mazda Turnaround," Journal of Japanese Studies 9.2:219-264 (Summer 1983).

29. A discussion of labor relations is beyond the scope of this paper, although I refer the reader to Cusumano, Chapter 3, as well as sources such as Aoki Satoshi, Nissan kyoeiken no kiki: roshi niju kenryoku shihai no kozo (The crisis of the Nissan group: The structure supporting the dual authority of management and labor), Tokyo, Chobunsha, 1980; and Yamamoto Kiyoshi, Jidosha sangyo no roshi kankei (Management-labor relations in the automobile industry), Tokyo, University of Tokyo Press, 1981.

Exhibit 1: Vehicle Productivity Adjusted for Vertical Integration, Capacity Utilization, and Labor-Hour Differences, 1965-1983

FY	GM, Ford, Chrysler[a]	Nissan	Toyota
Relative Scale (U.S. = 1.0)			
1965	1.0	0.9	1.5
1970	"	1.9	2.4
1975	"	1.7	2.6
1979	"	2.0	2.7
1983	"	1.9	2.2

Source: Derived from annual reports.

Notes: [a]This column indicates average figures for GM, Ford, and Chrysler, based on worldwide data.

[b] The *1983 figures for GM and Ford, but not for Chrysler, assumed the vertical integration levels of 1979.*

Exhibit 2: PRODUCTION SCALES ADJUSTED FOR VERTICAL INTEGRATION, 1965-1983

FY	GM	FORD	CHRYSLER	NISSAN	TOYOTA
1965	100	44	21	3	5
1970	100	72	34	16	21
1975	100	55	30	16	25
1979	100	54	15	16	24
1980	100	51	14	23	31
1983	100	53	13	20	26

Sources: Annual reports (Japanese versions for Nissan and Toyota) and Exhibit 7.

Exhibit 3: Fixed Assets (at Cost) per Estimated Labor Hour, 1965-1983

FY	GM, Ford, Chrysler	Nissan	Toyota
Relative Scale (U.S. = 1.0)			
1965	1.0	0.7	0.8
1970	"	0.9	1.3
1975	"	1.4	1.7
1980	"	1.4	1.7
1983	"	2.0	2.5

Source: Derived from annual reports.

Notes: Exchange rates are based on purchasing-power parity data for capital formation ($1.00 = 299 yen in 1975).
Rates for other years and constant values found by using the Japanese and U.S. price deflators for domestic non-residential fixed investment. For purchasing-power parity rates see Irving Kravis et al., World Product and Income: International Comparisons of Real Gross Product, Baltimore, Johns Hopkins University Press/World Bank, 1982, pp. 178-179.

Exhibit 4: Fixed Assets per Vehicle Produced, 1965-1983

Adjusted for Integration and Capacity Utilization			
FY	GM, Ford, Chrysler	Nissan	Toyota[a]
Relative Scale (U.S. = 100)			
1965	100	76	55
1970	"	42	54
1975	"	80	65
1979	"	86	108
1983	"	103	113

Sources: Annual reports (English versions for Nissan and Toyota).

Notes: [a]Figures for Toyota prior to 1983 are adjusted upward by 9% to account for the fixed assets of Toyota Motor Sales; this was the level of Toyota Motor Sales' fixed assets in the 2 years prior to the merger.

[b]Includes an estimate of 50% for accumulated depreciation not listed in Nissan's 1975 report. This estimate is based on data from other years.

Exhibit 5: JAPANESE AND U.S. AUTO PRODUCTION BY VEHICLE TYPE, SELECTED YEARS

	UNITED STATES		JAPAN	
YEAR	PRODUCTION	CARS	PRODUCTION	CARS
1941	5,901,322	64%	46,498	4%
1950	8,003,056	83	31,597	5
1955	9,169,276	86	68,932	29
1960	7,869,271	85	481,551	34
1965	11,057,366	84	1,875,614	37
1970	8,239,257	80	5,289,157	60
1975	8,985,012	75	6,941,591	66
1980	8,067,123	79	11,042,884	64
1985	11,541,725	71	12,271,084	62

Sources: Motor Vehicle Manufacturers Association of the U.S.; Wards' Automotive Yearbook; Japan Automobile Manufacturers Association.

Exhibit 6: Nissan and Toyota Production by Vehicle Type, 1941-8

NISSAN:	Production	% Small Trucks	% Standard Trucks	% Small Cars	% Standard Cars
1941	19,688	4.6	86.6	8.1	—
1950	12,458	34.0	54.8	6.9	—
1955	21,767	34.7	32.1	30.3	—
1960	115,465	42.9	8.8	47.7	—
1965	345,165	45.1	4.8	48.8	0.4
1970	1,374,022	32.9	1.0	63.8	1.6
1975	2,077,447	25.0	0.9	69.8	4.0
1980	2,644,052	23.7	1.9	69.1	4.3
1982	2,407,734	18.6	5.3	66.7	8.8
1983	2,482,540	17.8	6.8	66.0	8.9
TOYOTA:					
1941	14,611	—	98.1	—	1.4
1950	11,706	31.7	62.4	4.0	—
1955	22,786	40.3	26.5	32.5	—
1960	154,770	53.4	19.0	27.2	—
1965	477,643	45.8	4.3	49.2	0.2
1970	1,609,190	30.1	2.5	64.6	1.8
1975	2,336,053	22.7	3.4	68.1	5.3
1980	3,293,344	19.8	9.2	62.1	7.8
1982	3,144,557	18.0	9.4	62.8	9.0
1983	3,272,335	16.5	10.1	65.2	7.6

Sources: Japan Automobile Manufacturers Association; Toyota Jidōsha Kabushiki Kaisha, Kōhō shiryō; *Nissan Jidōsha Kabushiki Kaisha, "Nissan Jidōsha no gaiyō";* Nissan Jidōsha sanjū nen shi; Toyota Jidōsha sanjū nen shi; *Nissan Jidōsha Kabushiki Kaisha,* Jidōsha kōgyō handobukku *(1984).*

Note: [a]Bus production is included in the industry truck total for 1941.

EXHIBIT 7:

NISSAN CAR MODELS AND AVERAGE ANNUAL VOLUMES, 1950-1983

FY	MODELS	AVERAGE ANNUAL VOLUME/MODEL
1950	1	900
1955	2	3,000
1960	5	11,000
1965	7	24,000
1970	9	100,000
1975	11	140,000
1980	16	120,000
1981	16	117,000
1982	21	86,000
1983	20	93,000
1984	21	88,000

Sources: Calculated from Nissan Motor Co. Ltd., Data File 1984; Nissan Jidosha Kabushiki Kaisha (Nissan Motor Co. Ltd.), "Nissan Jidosha no gaiyo" (Overview of Nissan Motor, 1982) and Nissan Jidosha 30-nen shi (A 30-year history of Nissan Motor, 1964).

Exhibit 8: **Company and Group Integration, U.S.-Japan, 1965-1983** (%)

	Nissan		Toyota		GM	Ford	Chrysler
FY	**In-House**	**Group**	**In-House**	**Group**	**In-House**	**In-House**	**In-House**
1965	32	54	41	74	50	36	36
1970	29	52	35	66	49	39	36
1975	22	50	30	73	45	36	36*
1979	26	70	29	74	43	36	32
1980	26	73	29	76	—	—	34
1981	26	71	28	75	—	—	31
1982	26	75	26	70	—	—	34
1983	26	78	26	73	—	—	28

Sources: Derived from annual reports.

Notes: *Estimate, assuming that the level of payments to suppliers (as a percentage of sales) in 1975 equaled the average for 1974 (64.1%) and 1976 (64.3%), since Chrysler did not publish this figure in 1975.

In-house vertical integration is defined as internal manufacturing and other operating costs divided by sales minus operating profits. Group vertical integration is defined as internal operating costs plus operating costs paid to affiliates (20%-equity minimum) divided by sales minus operating profits.

Since the Japanese and U.S. firms do not publish comparable data, I employed the following methodology and assumptions to construct the table above. For Nissan and Toyota (including Toyota Motor Sales), I multiplied the percentage of manufacturing costs for small cars not subcontracted (see Table 45) by total manufacturing costs listed in the yūka shōken hokokusho *(Japanese 10-K reports), added other operating expenses incurred in house (executive and other non-manufacturing employee compensation, retirement and severance payments, and depreciation), and divided by sales minus operating profits. For group integration, I added operating costs paid to affiliates, listed in the notes to the balance sheets in the Japanese reports, to in-house costs. For the U.S. firms, I subtracted payments to suppliers from sales minus operating profits and divided by sales minus operating profits. GM and Ford stopped publishing data on payments to suppliers after 1979, so I could not calculate their levels of integration for 1980-1983.*

The Japanese figures are estimates, therefore, assuming that the percentages Nissan and Toyota published regarding subcontracting are accurate, and that total subcontracting was roughly equal to that for small cars.

Exhibit 9: **Average Monthly Wages per Employee (Excluding Bonuses)—Nissan and Toyota Groups, 1983**

(yen, number of employees)

Company	Wages	Scale	Employees
Nissan Group			
Nissan	283,457	100	59,335
Fuji Heavy Industries	207,794	73	13,928
Nissan Diesel	183,070	65	6,685
Nissan Auto Body	270,391	95	7,200
Nihon Radiator	231,243	82	4,839
Aichi Machine	249,006	88	4,403
Atsugi Auto Parts	237,261	84	4,314
Kantō Seiki	215,251	76	3,041
Ichikō Industries	268,229	95	3,074
Daikin Works	289,485	102	1,597
Ikeda Bussan	197,557	70	1,572
Fuji Kikō	225,698	80	1,503
Jidōsha Denki	150,972	53	1,545
Kasai Industries	246,485	87	1,128
Fuji Ironworks	166,543	59	1,103
Tochigi-Fuji Industries	236,446	83	770
Tokyo Sokuhan	255,138	90	585
15 Subsidiaries Average	228,185	81	43,359
Toyota Group			
Toyota	301,247	100	58,706
Daihatsu	274,239	91	10,482
Hino	287,698	96	8,462
Nippon Denso	232,935	77	29,210
Aisin Seiki	217,404	72	7,971
Toyota Auto Body	202,718	67	6,576
Toyoda Automatic Loom	269,423	89	6,400
Kanto Auto Works	271,354	90	5,727
Toyoda Gōsei	251,180	83	4,630
Aichi Steel	289,310	96	3,463
Toyoda Machine Works	195,239	65	3,552
Koito Works	195,495	65	3,259
Aisan Industries	180,807	60	2,591
10 Subsidiaries Average	230,587	77	73,379

Source: Toyo Keizai Shimposha (Oriental Economist), Kaisha shikiho (Company quarterly reports),

Exhibit 10: **Net Value-Added Productivity (VAP) at Nissan and Toyota Subsidiaries, 1960-1983** (number of firms and employees; 1000 yen in constant 1983 values)

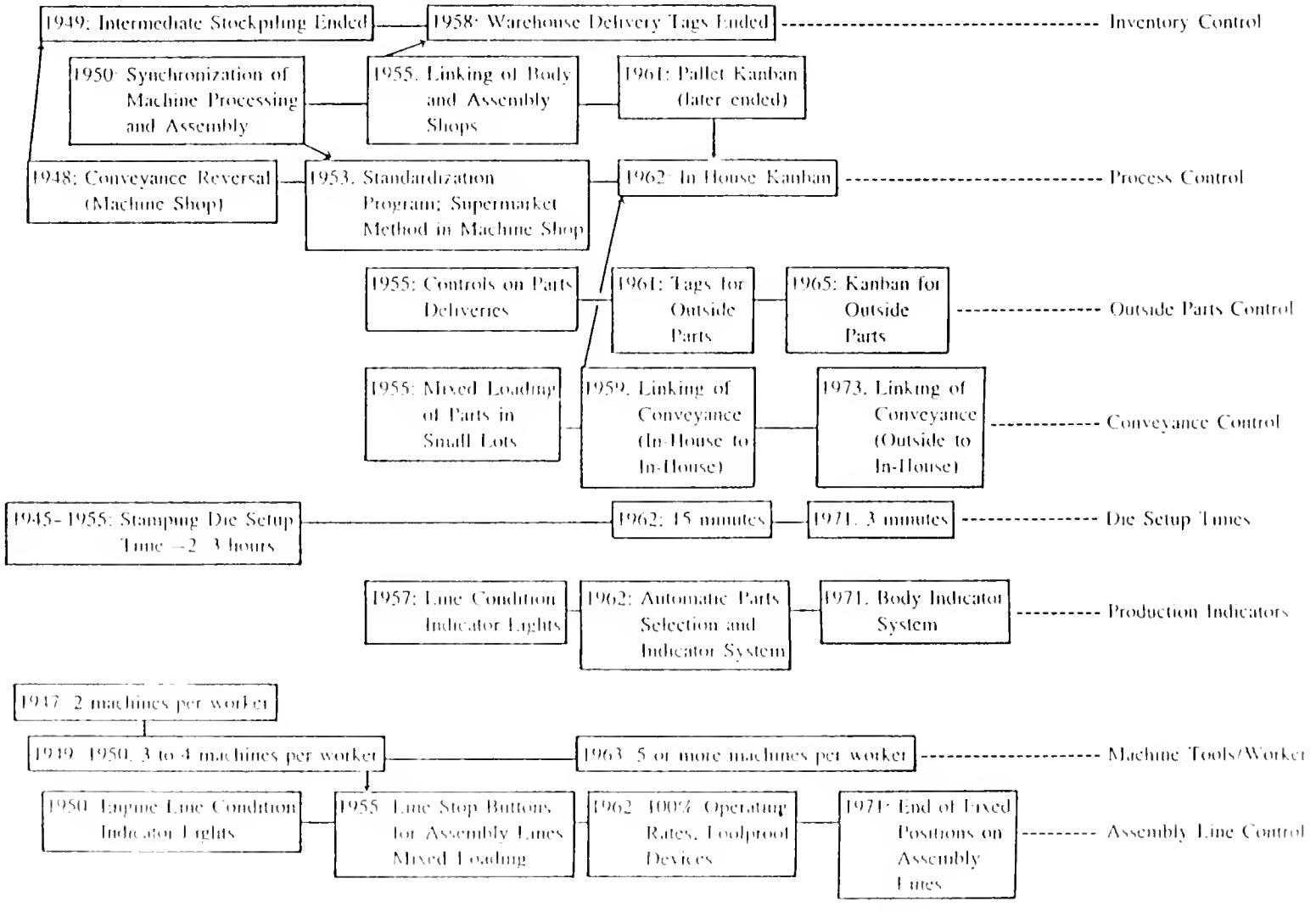
	Nissan Subsidiaries (N)				Toyota Subsidiaries				
FY	**Firms**	**Employees**	**VAP**	**Scale**	**Firms**	**Employees**	**VAP**	**Scale**	**N = 100**
1960	2	3,700	1,811	100	6	15,800	2,130	100	118
1965	3	8,800	2,062	114	6	24,200	2,214	104	107
1970	3	15,100	3,994	221	7	42,300	4,057	190	102
1975	4	20,300	4,607	254	7	48,600	4,583	215	99
1980	6	29,300	5,342	295	8	58,900	6,197	291	116
1981	6	31,100	5,258	290	8	62,600	6,158	289	117
1982	6	31,600	4,872	269	8	64,700	5,918	278	121
1983	6	31,500	5,425	300	8	66,600	6,495	305	120

Notes: Constant values found by using the Japanese consumer price index for private transportation.

The years in which subsidiaries appear in this table follow their first public filing of corporate reports and inclusion in the Fuka kachi bunseki *series. For the Nissan group, these were Nissan Auto Body and Nissan Diesel in 1960; add Aichi Machine in 1965, Nihon Radiator in 1975, Atsugi Auto Parts and Kantō Seiki in 1980. For the Toyota group, these were Aichi Steel, Toyota Auto Body, Kantō Auto Works, Toyoda Machine Works, Nippon Denso, and Toyoda Automatic Loom in 1960; add Aisin Seiki in 1970 and Toyoda Gōsei in 1980.*

Source: Nihon Seisansei Honbu (Japan Productivity Center), Fuka kachi bunseki (Value-added analysis), Tokyo, annual.

Exhibit 11: Development of the Toyota Production System, 1948–1973



Source: Ohno Taiichi, *Toyota Seisan Hoshiki* (The Toyota production system, 1978), pp. 228–229.

Exhibit 12: UNADJUSTED VEHICLES PER WORKER AT TOYOTA, NISSAN, GM & FORD, 1955-1964 & SELECTED YEARS

FY	TOYOTA	NISSAN	GM	FORD
1955	4	3	8	12
1956	8	6	7	10
1957	13	7	6	10
1958	12	8	6	9
1959	14	9	7	11
1960	15	12	8	12
1961	16	14	7	11
1962	16	15	9	11
1963	19	17	9	12
1964	20	18	9	12
1970	38	30	8	12
1980	56	41	10	10
1983	58	42	11	15

Sources: Annual reports.

Exhibit 13: Inventory Turnover Comparison, 1955-1983

Period	Nissan	Toyota	GM	Ford	Chrysler
1955-1959	7	11	7	9	9
1960-1964	14	15	7	8	9
1965-1969	14	26	7	7	8
1970-1974	14	23	6	7	6
1975-1979	14	26	8	9	6
1980	17	23	8	7	5
1981	15	21	9	8	6
1982	16	29	9	9	7
1983	19	36	12	11	11

Sources: Annual reports.

Exhibit 14: Inventory Turnover Comparison, 1955-1983

FY	Nissan	Toyota
1955	4.5	7.7
1956	7.2	14.9
1957	6.1	10.6
1958	5.9	9.8
1959	8.9	10.9
1960	12.0	10.4
1961	13.9	11.0
1962	14.5	12.4
1963	16.6	18.4
1964	14.9	20.7
1965	12.7	20.9
1966	13.2	27.7
1967	14.0	28.6
1968	14.5	27.8
1969	14.8	26.7
1970	12.5	23.5
1971	14.4	22.8
1972	17.3	25.8
1973	15.8	24.2
1974	11.0	20.5
1975	13.5	21.1
1976	13.3	24.2
1977	13.3	26.9
1978	13.5	28.4
1979	16.7	27.4
1980	17.4	22.5
1981	15.1	21.3
1982	16.2	28.5
1983	19.4	36.3

Sources: Annual reports.

Exhibit 15: Inventory Turnover in the Nissan and Toyota Groups, 1965-1983

	1965-1969	1970-1974	1975-1979	1980-1983
Toyota Group				
Toyota Auto Body	27	52	41	43
Toyoda Automatic Loom	9	11	20	26
Kantō Auto Works	19	76	72	70
Nippon Denso	13	12	14	19
Aichi Steel	6	8	7	10
Aisin Seiki	14	17	29	30
Toyoda Machine	6	4	6	7
Toyoda Gōsei	—	—	39	42
• Daihatsu	17	20	32	36
• Hino	10	16	20	21
Nissan Group				
Nissan Auto Body	28	36	51	63
Nissan Diesel	8	8	8	9
Nihon Radiator	—	11	15	21
Kantō Seiki	—	—	22	28
Aichi Machine	16	24	32	32
Atsugi Auto Parts	—	—	15	20
• Fuji Heavy Industries	8	7	9	10
Other Automakers				
• Honda	11	12	12	13
• Mazda	13	10	14	20
• Isuzu	12	10	10	10

Source: Fuka kachi bunseki.

Exhibit 16: SPECTRUM OF JAPANESE RESPONSES

MOST RADICAL	COMPROMISE	CONVENTIONAL
TOYOTA	NISSAN	U.S., EUROPE
FASTEST SETUP	FAST SETUP	SLOW SETUP
SMALLEST LOTS	MEDIUM LOTS	LARGE LOTS
PULL SYSTEM	PUSH SYSTEM	PUSH SYSTEM
CENTRALIZED	SOME DISPERSAL	MUCH DISPERSAL
LINE INSPECTION	SAMPLING	SAMPLING
LINE MAINTENANCE	LINE MAINTENANCE	SPECIALIZED
LOW IN-HOUSE VI	LOW IN-HOUSE VI	HIGH IN-HOUSE VI
HIGHEST GROUP VI	HIGH GROUP VI	LOW GROUP VI
HIGHEST TURNOVER	HIGH TURNOVER	LOW TURNOVER
HIGHEST PRODUCTIVITY	HIGH PRODUCTIVITY	LOW PRODUCTIVITY
FOLLOWERS:	FOLLOWERS:	FOLLOWERS:
LATE 1960S: DAIHATSU, HINO	ISUZU, SUBARU, HONDA, MITSUBISHI	1930S: NISSAN, ISUZU
MID-1970S: MAZDA		
LATE 70S & 80S: NISSAN, ETC. (PARTIAL)